



A Localized National Engineering Education and Research Outreach Model for Engineering Workforce Pipeline

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Dr. Chegini received his doctorate, masters, and bachelors' degrees in Mechanical Engineering from Old Dominion University, Norfolk, Virginia. His academic background is in thermal science of mechanical Engineering and his areas of expertise is in multi-phase computational fluid dynamics (CFD). Dr. Chegini joined Hampton University School of Engineering & Technology as an associate professor in September 2002. Before joining Hampton University, he served as a faculty and chair of Mechanical Engineering department at K.N.T. University of Technology in Tehran, Iran for over 12 years. Currently he is working as a CO-PI on a research project funded by Department of Energy.

Mrs. Chandra T Oaks-Garcia, Time Out 4U, Inc.

Professional Biography

Chandra T. Oaks-Garcia is a secondary technology teacher in the Career and Technical Education Program. She earned her B.S in Mechanical Drafting and Design Technology from Alabama Agriculture and Mechanical University and her M.Ed. from Averett University. She is currently studying postgraduate STEM Education at Old Dominion University. Mrs. Oaks-Garcia's expertise is in the field of Computer-Aided-Design. She has over twenty-five years of professional experience as a Senior Designer with extensive knowledge in 3D Modeling Software and Computer-Integrated-Manufacturing collectively in the areas of Civil, Electrical, and Mechanical Design.

Mrs. Oaks-Garcia has supports her local school districts within the community working with the National Institute of Aeronautics (NIA), Hampton, Virginia as a "Teacher In Residence" in 2009. She served on conference planning committees for VTEEA and TSA locally over a period of time. She also worked with the Division's Career Academy Team for Hampton City Schools in 2010.

Mrs. Oaks-Garcia has proudly served a community of learners in the Hampton City School District in various capacities for the past fifteen (15) years. For her teaching strategy, Mrs. Oaks-Garcia incorporates real world learning into the classroom to promote and enhance student's critical thinking and problem solving skills. In September 2001, her Future Engineering Team consisting of 11th and 12th grade students of Hampton High School tackled a real-life engineering challenge following the terrorist attacks in three U.S. locations by designing, manufacturing and defending solutions to increase airline safety after 911. Mrs. Oaks-Garcia and her engineering students were featured in the Hampton Daily Press and on WAVY TV in 2001, and also in the NASA Newsletter in March 2002 for their innovative design solutions.

Mrs. Oaks-Garcia currently teaches STEM and Technology Education at the secondary level. She serves as a mentor for Hunter B. Andrews's team of STEM students in the Virginia Ship Repair Foundation Annual Competitions. In 2010, the STEM students won 1st place with their futuristic Ship Design. Currently, Mrs. Oaks-Garcia is the facilitator of the after school CAM program at Hunter B. Andrews Pk-8 School. She is committed to empower the next generation of 21st century learners at an early age through STEM.

Mrs. Oaks-Garcia is the founder and CEO of Time Out 4U Incorporated, Youth Engineering Program, established in 2013. She serves as the Administrator for Operations and oversees activities. The organization is involved in grant-supported projects focused on Computer Additive Manufacturing and STEM Outreach for after school programs. The organization sponsors an annual STEM Symposium.



Mrs. Oaks-Garcia is from Mobile Alabama and currently resides with her husband in Hampton, Virginia and their four sons.

Dr. Vadivel Jagasivamani, Hampton University

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Abstract

A consortium of eight universities and three US Department of Energy (DOE) national laboratories was established in 2014. This consortium is implementing a model for industry, academia, and government partnership focused on pipeline development of skilled workforce through advanced manufacturing. This paper reports on the expansion of STEM outreach activities with a focus on advanced (additive) manufacturing for K-20 as well as the enhancement of education and training of individuals as implemented in one of the consortium member institutions. The outreach components involved the training of undergraduate students through summer exchange at universities as well as through summer internship placement at national laboratories. A local outreach to middle / high schools was established through the implementation of an advanced manufacturing skills development after-school program for middle school students. The paper also presents the model curriculum for the outreach program and shows the integration of undergraduate students and K-12 teachers working together.

Introduction to MSIPP Program

In 2012, the National Nuclear Security Agency (NNSA) established the Minority Serving Institutions Partnership Program (MSIPP). This program is a consortium-based program with the principal goal of establishing a sustainable career pipeline for minority students pursuing Science, Technology, Engineering, and Mathematics (STEM) degrees. The collaboration between Historically Black Colleges and Universities (HBCUs) and DOE/NNSA sites and labs in STEM disciplines in the area of advanced manufacturing brings a heightened awareness of nationally important research at NNSA plants to HBCUs with a common interest in STEM research fields. To attain the principal goal of establishing a sustainable HBCU/MSI workforce pipeline of STEM professionals, the MSIPP is focusing on the following four areas:

- Building and maintaining a skilled STEM pipeline of students that will be capable of meeting future DOE/NNSA needs;
- Establishing collaborative efforts between the HBCUs and the DOE plants and labs to foster advanced research;
- Establishing collaborative relationships between the HBCUs and the DOE plants and labs to enhance the education and training of individuals in advanced manufacturing and technology development;
- Establishing collaborative relationships between the HBCUs and the DOE plants and labs to expand the STEM outreach opportunities with a focus on advanced manufacturing for K-16 students.

Several consortiums were established by this program and Hampton University is currently a member of the Consortium for Advanced Manufacturing (CAM). This paper focuses specifically on the outreach component of the consortium with a purpose to educate and introduce students into the STEM field by providing innovative and interactive program focused on the advanced manufacturing topics.

Collaboration Structure

NNSA developed the initial structure by creating eight different consortiums, however later, in 2014, the decision was made to reduce the number of consortiums from eight to four to avoid duplicate effort. The two Advanced Manufacturing consortiums were merged into one consortium. A lead university and several other universities along with a design agency and/or production site were assigned within each consortium. The CAM is comprised of the following HBCUs and industry partners:

- North Carolina A&T (NC A&T) – Lead University
- Alabama A&M (AAMU)
- Clark Atlanta University (CAU)
- Hampton University (HaU)
- Honeywell FM&T Kansas City Plant (KCP)
- Howard University (HoU)
- Lincoln University (LU)
- Oak Ridge National Laboratory (ORNL)
- Southern University of New Orleans (SUNO)
- University of the District of Columbia (UDC)
- Y-12 National Security Complex (Y-12)

Outreach Component Goals

The intent of the CAM STEM pipeline outreach component is to improve STEM educational experiences of students in K-16 so that participants increase their employability and enter the job market with experiences in STEM gained from a young age. The CAM provides a host of professional expertise and resources that allow middle, high school, undergraduate and graduate students to experience a myriad of STEM related activities at the various campuses. The outreach component of the CAM assists individual universities to plug gaps that currently exist in their individual STEM programs and activities targeted at their respective communities, stakeholders, and future student populations. The inclusion of KCP, Y-12, and ORNL strengthens the CAM partnership by providing students with opportunities to expand their educational experiences via lab visits, career exposure, and faculty-student internships.

Outreach Project Goals: The pipeline focus of CAM is the enhancement of the workforce pool. All projects supported by the CAM outreach component meet one or some of the project goals as outlined below:

- To increase the number of students, internships, programs, and collaborative research between CAM partners;
- To provide and preserve educational opportunities for underrepresented students in STEM in grades K- 16;
- To maintain/raise academic standards by enabling learners to acquire competencies needed for success in college;
- To provide opportunities for students in grades K-16 to make connections between in-class curricula and its significance in a real world setting;

- To provide opportunities for students in grades K-16 to develop skills and attitudes necessary for the attainment of academic, career, and life goals;
- To provide opportunities for students in grades K-16 to understand and utilize the scientific and build/design methods of inquiry;
- To provide opportunities for students in grades K-16 to use appropriate technology related to Advanced Manufacturing and other STEM career fields;
- To ensure proper placement by assessing each learner's level of preparedness for secondary, post-secondary, and graduate school coursework.

Outreach Component Efforts at Hampton University

Developing a Regional High School Expansion Program Model: The goal of this program is to enhance relations between consortium members and regional schools by developing a comprehensive High School Expansion Model with an Advanced Manufacturing focus. As part of the Regional High School Expansion Program effort, Hampton University is currently working on the pilot Advanced Manufacturing STEM after school program at Hunter B. Andrews PK-8 school in the city of Hampton, VA. This pilot program is serving as one of the components for implementing the CAM outreach's regional pipeline schools expansion model. The program targets 15 to 18 students, who meet on twice a week (currently Mondays and Wednesdays from 4pm to 5pm) and is being coordinated by a designated STEM teacher at the school with the help of undergraduate Hampton University engineering students. The initial project effort was mainly local, but the project is expanding the collaborative reach by engaging two CAM industry partners. The program is projected to grow into the community of teachers and students outside Hunter B. Andrews through the mobility of TimeOut4U Inc. partnership.

Hampton University teamed up with TimeOut 4U, Inc. (www.timeout4u.org) - a non-profit focused on engineering programs for youth that strives to diversify the 21st century workforce by broadening STEM exposure and career readiness to minorities and other underrepresented youth during early academic years to explore other funding opportunities. The National Society of Black Engineers (NSBE) student chapter at Hampton University has also volunteered to help with the program. During the first year, a program curriculum was developed in collaboration with TimeOut 4U, Inc. The curriculum breakdown included the following general modules: overview of advanced manufacturing; career exploration; computer-aided design; creative problem solving; manufacturing career track; rapid prototyping & 3D printing; and workplace readiness skills. During the first year all the modules were delivered by the program coordinator and the undergraduate engineering students. The program is being enhanced to include module delivery by industry partners, and contributors from other collaborating university partners. Hampton University leads the project and coordinates the partnerships as well as seeks resources for sustainability. Collaborating partner universities provide material support based on past experiences in other outreach programs (e.g. relevant modules/projects). In the second year, Hunter B. Andrews will continue hosting the after-school program and TimeOut 4U, Inc. will disseminate the program through holding mobile workshops to the community and technology teachers. The industry partners will give online based workshops to the students via skype type of delivery. Each partner commits to delivering at least one module. The industry presentations to the students are aligned with the modules focused on careers.

The program activities require the participants to engage in STEM related modules demonstrating the infusion of engineering concepts and applied mathematics highlighting manufacturing advancements. Activities are planned for the academic year period for a minimum of 50 hours. Advanced manufacturing activities that have been developed at other consortium universities for the summer programs are incorporated into the program as well as the advanced manufacturing program modules developed specifically for the program. The program coordinators focus on:

- Coordinating program activities and projects;
- Developing and ensuring quality project activities;
- Recruiting program participants;
- Maintaining and tracking data on student participants;
- Planning, implementing, and managing regular activities;
- Enhancing the program curriculum materials;
- Training and supervising the undergraduate students and volunteers.

As an example, the program modules connect the engineering design concepts with practical applications in real-world engineering, where student perform problem solving, design, manufacturing, and testing of products, and the program coordinators train the students in CAD tools and 3D printing technology.

Students begin by learning manufacturing and rapid prototype processing using the 3D printer. To capture the imagination of middle school students and build interest in manufacturing, students sketch and design a useful object that will be made using a 3D printer. Opportunities are introduced to allow students to create, refine, and/or assemble a number of items, giving their work an end result they can hold in their hands.

Program Curriculum:

Module #1:	Introduction Week <ul style="list-style-type: none">- What is manufacturing – Reverse Engineering/Systems- Explore current and emerging careers in manufacturing
Module #2:	What Makes A Great Print? <ul style="list-style-type: none">- Design Concepts- Problem Solving Skills
Module #3:	Explore and Declare Your Idea! <ul style="list-style-type: none">- Engineering Design Process- Eco-Green- Newton Laws of Motions – Energy Transfer
Module #4:	Creating a Design: <ul style="list-style-type: none">- Computer Software/Applications (Inventor/AutoCAD)- Technical Drawing
Module #5:	What is 3D Printer/Additive Manufacture? <ul style="list-style-type: none">- Identify what 3D printers currently can and cannot print.
Module #6:	How to Print I: Explain how 3D printer technology works <ul style="list-style-type: none">- Limitations of 3D Printing

- Working within Constraints
- Module #7: How to Print II: Making a Connection
 - Computer-Integrated Manufacture
 - Input-Process-Output
- Module #8: Rapid Prototype and Real World Testing
 - Quality and Efficiently
 - Functionality
- Module #9: Modify and Market
 - Communicate
 - Feedback
- Module #10: Explore Types of Manufacturing, and Related Careers
 - Colleges and Universities
 - Companies and Opportunities

Some of the results obtained from implementing the curriculum above included the students brainstorming and selecting a popular toy design to demonstrate what a 3D printer can do. The process of the activity included utilizing 3D modeling software such as AutoDesk Inventor. They were able to implement the engineering design process to generate rapid prototypes and concluded with real world testing. Once all components were manufactured and assembled, they performed real world testing for functionality, ergonomics, and efficiency. Students were effective in problem solving, modifying to improve upon their 3D printed product. Excitement and curiosity grew among the students when they saw their very own drawing becoming a reality within hours. Students have gained a clear concept of STEM related educational pathway to careers in advanced manufacturing engineering from their very own detail research and oral presentations. Images of their toy product are shown below in figures 1, 2, and 3.

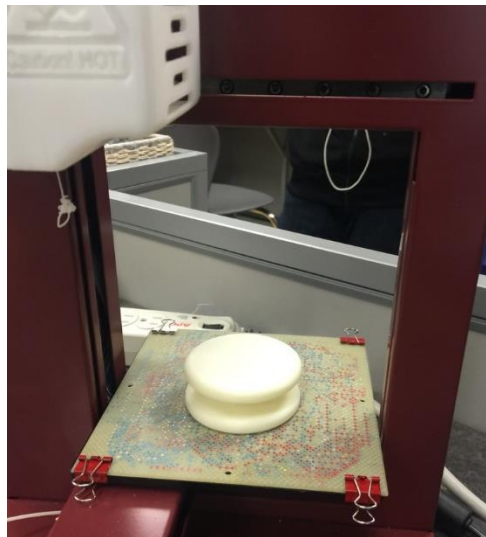


Figure 1: Example toy product designed and printed by students.

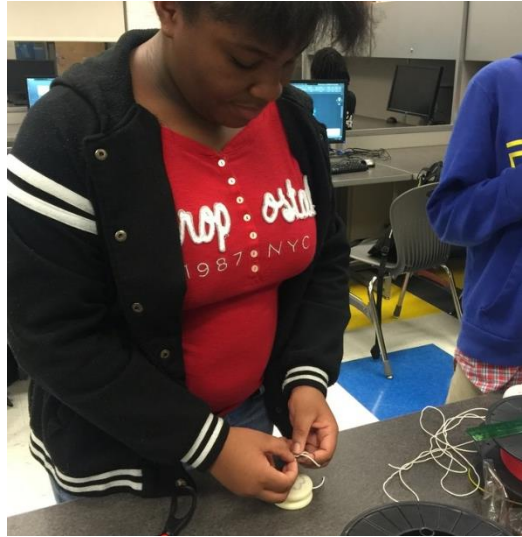


Figure 2: Assembling of toy product components.

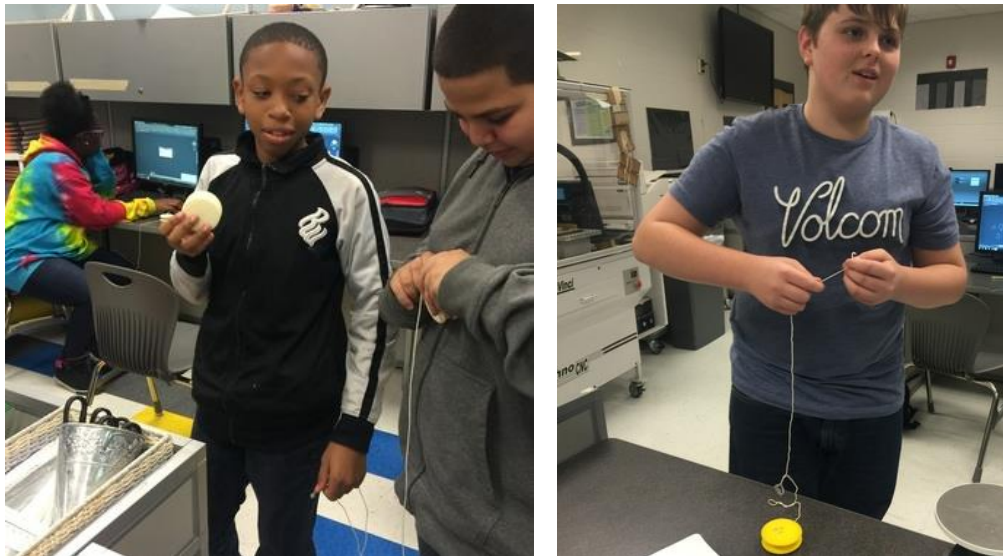


Figure 3: Toy product testing.

Summer Exchange Program: The consortium sponsors students from partner universities to enhance their skills by exposing them to workforce skills that may be unavailable at their home institutions. The program also assists partner institutions in enhancing their outreach program offering through training undergraduate students to support programs at their home institutions as well as co-advising. Hampton University initiated an undergraduate summer exchange program with Lincoln University. The students assist in a two-week summer STEM program for a period of up to four weeks. During the summer assignment, students primarily serve as one of the program counselors for the Business of Engineering summer program at Hampton University along with engineering and business undergraduate students. As part of the responsibilities, students:

- Assist in preparing project activities for the Business of Engineering Summer program at Hampton University;
- Assist in project enhancements and implementation;
- Are available each program day from 8:45am- 4:15pm;
- Attend each field trip and assist with logistics;
- Accompany students to cafeteria for lunch;
- Assist and oversee completion of student projects and activities;
- Serve as a role model by limiting use of electronics during instructional periods;
- Organize and oversee HU scavenger hunt;
- Encourage positive team dynamics;
- Organize/create program newsletter and assist with closing ceremony program (i.e. superlatives, assist students with PowerPoint, overall program organization);
- As a team, complete program summary in paper format (paper to include literature review, data collection from surveys, program synopsis);
- Learn about the CAM after-school outreach program on advanced manufacturing;
- Learn the operation of Ultimaker2 3D printer.

Industry Day: The consortium outreach model also offers an Industry Day initiative where workshops and lectures in advanced manufacturing and/or other engineering areas of interest are presented to students and faculty of university partner outreach programs. Industry personnel from industrial partners are invited to university partners for a day to connect with students and partners as well as learn about collaboration opportunities. At Hampton University, the industry day plan involves having workshop presentations on modeling and simulation to students and faculty as well as presentations on advanced manufacturing to middle school students.

Tutoring: The outreach program is extended to most of the undergraduate students through tutoring programs offered by each university partner. The tutoring program at Hampton focuses on engineering courses mainly first year and second year courses. Third and fourth year courses are also considered for tutoring based on the availability of tutors.

K-12 STEM Enrichment Program: The teachers in the K-12 schools of partner universities are also offered opportunities for professional development. The university partners recruit teachers from their region to attend programs such as the SECME Summer Institute. Hampton University has supported a local school teacher to attend SECME and the teacher supports the regional high school expansion program in turn. SECME has a 40 year legacy of being a professional development Institute dedicated to focusing on equity in STEM initiatives by bringing together K-12 educators, university faculty, and industry and government experts promoting inclusion in learning and doing STEM. The selected K-12 teachers receive training on the current pedagogies of STEM and follow up with strategies to promote STEM in their schools and region through formal and informal learning environments.

Outcomes and Assessment

Several outreach initiatives have been started at Hampton University as part of the CAM project supporting the broad goal of establishing collaborative relationships between the

HBCUs and the plants and labs to expand STEM outreach opportunities with a focus on advanced manufacturing for K-20 students. These included a Regional High School Expansion program, Summer Exchange program, Industry Day, and Tutoring program. The general outcome for all these projects is to inspire the students to become engineers or to at least to delve into the STEM field and these programs help brace students for their career path in the STEM field by challenging them with obstacles that require an engineering design process.

The outreach component committee within the CAM holds an annual Program Assessment conference with the purpose of presenting the oral and poster program progress reports, discussing the effectiveness of the projects, discussing plans of sustaining the program, and providing an overall guidance for the outreach component. The metrics for the assessment include the number of students targeted by the outreach program, assessment of the knowledge gained by the students, their feedback regarding the program, and the student retention rate within the STEM field.

Conclusions

A collaboration program has been established between eight HBCUs and three DOE/NNSA plants and national labs with the goal of building a successful model for sustainable workforce pipeline within the STEM field with applications for advanced manufacturing topics. The outreach part of the consortium has been tasked with developing programs and projects that would involve K-20 students and attract and retain them in the STEM area. Several such projects have been developed and initiated at Hampton University, including the Regional High School Expansion, Summer Exchange, Industry Day, and Tutoring programs. It is possible to use this model approach in local, national, and international engineering/STEM collaborations.